

## INTRODUCTION

The finite element method provides a powerful technique for analysis of stresses and movements in earth masses, and it has already been applied to a number of practical problems including embankment dams, open excavations, braced excavations, and a variety of soil-structure interaction problems.

If the results of soil deformation analyses are to be realistic and meaningful, it is important that the stress-strain characteristics of the soil be represented in the analyses in a reasonable way. This is difficult because the stress-strain characteristics of soils are extremely complex, and the behavior of soil is nonlinear, inelastic, and highly dependent on the magnitudes of the stresses in the soil.

The hyperbolic stress-strain relationships described in this report were developed in an attempt to provide a simple framework encompassing the most important characteristics of soil stress-strain behavior, using the data available from conventional laboratory tests. These relationships have been used in finite element analyses of a number of different types of static soil mechanics problems (11, 12, 13, 22, 23, 24, 31, 32, 35, 40), and values of the hyperbolic parameters have now been determined for about 150 different soils.

The purposes of this report are to describe the hyperbolic relationships, to outline the procedures for evaluating the hyperbolic parameters, and to present parameter values determined from drained and undrained tests on a number of soils.

In a previous report, Wong and Duncan (45) outlined procedures for determination of stress-strain and volume change parameters for use in

nonlinear finite element analyses of stresses and movements in earth masses. In that report, the parameters employed to represent nonlinear and stress-dependent stress-strain and volume change behavior were:

- (1) Tangent values of Young's modulus ( $E_t$ ) which vary with confining pressure and the percentage of strength mobilized, and
- (2) Tangent values of Poisson's ratio ( $\nu_t$ ) which vary with confining pressure and the percentage of strength mobilized.

Subsequent studies have shown that the volume change behavior of most soils can be modelled with equal accuracy by assuming that the bulk modulus of the soil varies with confining pressure, and is independent of the percentage of strength mobilized. At high stress levels this assumption provides a more reasonable means of representing the mechanical properties of soils.

This report outlines procedures which may be used to determine the required Young's modulus and bulk modulus parameters from conventional laboratory test data. Specifically, the report is concerned with the use of the following parameters to represent the nonlinear and stress-dependent stress-strain and volume change behavior of soils:

- (1) Tangent values of Young's modulus ( $E_t$ ) which vary with confining pressure and the percentage of strength mobilized (exactly the same as in the previous report by Wong and Duncan), and
- (2) Values of bulk modulus ( $\beta$ ) which vary with confining

pressure and which are independent of the percentage of strength mobilized.